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NASA-16121 (June 2004)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Superseding NASA-16121 (December 2003)

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SECTION 16121

FIBER OPTIC CABLE
06/04

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section covers requirements for fiber optic cable systems.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

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The publications listed below form a part of this section to the extent referenced:

ASTM INTERNATIONAL (ASTM)

ASTM C 338	(1993; R 2003) Softening Point of Glass
ASTM D 4976	(2002) Standard Specification for Polyethylene Plastics Molding and Extrusion Materials

ELECTRONIC INDUSTRIES ALLIANCE (EIA)

EIA 455-104A	(2000) FOTP-104 Fiber Optic Cable Cyclic Flexing Test
EIA 455-164A	(1991) FOTP-164 Single-Mode Fiber, Measurement of Mode Field Diameter by Far-Field Scanning
EIA 455-165	(1993) FOTP-165 Single-Mode Fiber, Measurement of Mode Field Diameter by Near-Field Scanning

EIA 455-167A	(1992; R 2000) FOTP-167 Mode Field Diameter Measurement Variable Aperture Method in the Farfield
EIA 455-168A	(1992) FOTP-168 Chromatic Dispersion Measurement of Multimode Graded-Index and Single-Mode Optical Fibers by Spectral Group Delay Measurement in the Time Domain
EIA 455-169A	(2001) FOTP-169 Chromatic Dispersion Measurement of Optical Fibers by the Phase-Shift Method
EIA 455-25C	(1996) FOTP-25 Repeated Impact Testing of Single-Mode Fiber Optic Cables and Cable Assemblies
EIA 455-30B	(1991) Frequency Domain Measurement of Multitude Optical Fiber Information Transmission Capacity
EIA 455-33A	(1988) FOTP-33 Fiber Optic Cable Tensile Loading and Bending Test
EIA 455-41	(1993) FOTP-41 Compressive Loading Resistance of Fiber Optic Cables
EIA 455-46A	(1990) FOTP-46 Spectral Attenuation Measurement for Long-Length, Graded-Index Optical Fibers
EIA 455-47B	(1992) FOTP-47 Output For Field Radiation Pattern Measurement
EIA 455-51A	(2001) FOTP-51 Pulse Distortion Measurement of Mulitmode Glass Optical Fiber Information Transmission Capacity
EIA 455-53A	(2001) FOTP-53 Attenuation by Substitution Measurement for Multimode Graded-Index Optical Fibers or Fiber Assemblies Used in Long Length Communications Systems
EIA 455-78B	(2002) Optical Fibres - Part 1-40: Measurement Methods and Text Procedures - Attenuation
EIA 455-80B	(1996) FOTP-80 Cutoff Wavelength of Uncabled Single-Mode Fiber by Transmitted Power
EIA 455-81B	(2000) FOTP-81 Compound Flow (Drip) Test for Filled Fiber Optic Cable
EIA 455-82B	(1991) FOTP-82 Fluid Penetration Test for Fluid-Blocked Fiber Optic Cable

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FED-STD 595	(1994b) Colors Used in Government Procurement

1.2 GENERAL REQUIREMENTS

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NOTE: If Section 16003 GENERAL ELECTRICAL PROVISIONS is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.
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Section 16003 GENERAL ELECTRICAL PROVISIONS applies to work specified in this section.

Fiber optic cable shall consist of optical fibers, strength member[s], and jacketing. Associated components shall include optical fiber connectors, optical patch panels, terminal bay cabinets, and splice closures as indicated. Fiber optic cables shall be installed in inner duct in the existing cable duct and manhole system and/or directly buried to the facility. Fiber optic terminal shall be located in existing facility buildings.

References in this section to cable shall refer to fiber optic cable.

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.
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The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES in sufficient detail to show full compliance with the specification:

SD-01 Preconstruction Submittals

The following preconstruction submittals shall be submitted to the Contracting Officer for approval and approved [30] [_____] calendar days prior to installation.

Qualifications
Quality Assurance Plan

SD-03 Product Data

Manufacturer's product data shall be submitted for the following items. Data shall include a complete list of parts, special tools, and supplies with current unit prices and source of supply.

Optical Fibers
Fiber Optic Cable Design
Splice Organizers
Pre-Connected Cable Assembly
Fiber Optic Terminal Cabinets
Optical Patch Panel Assemblies

SD-06 Test Reports

Contractor test reports shall be submitted for approval to the Technical Representative not later than [14] [_____] calendar days after the completion of each test.

Factory Test Certificates
Single and Multi-mode OTDR Test
End-to-End Attenuation Tests
End-to-End Bandwidth Tests

1.4 QUALIFICATIONS

Cable construction work shall be performed by construction personnel who have had at least [3] [_____] years experience in placing cables in conduit, cable trays, and underground duct systems.

Fiber optic cable splices, terminations and testing shall be made by journeymen cable splicers who have had a minimum of [1] [_____] year experience in splicing and terminating fiber optic cables. Personnel working pursuant to this section, may at the Contracting Officer's option, be required to demonstrate technical competence by performing sample work [and/or by displaying their state qualifications/certificates], at no additional cost to the Government.

Each person who is to perform fiber optic cable splicing shall perform a minimum of one acceptable sample splice and termination. Sample splices and terminations shall not be incorporated in the job.

A Quality Assurance Plan shall be submitted for fiber optic cable systems consisting of detailed procedures defining methods to ensure compliance to contract drawings and specifications by drawing control, inspection and procurement records, test plan showing when and how each system will be tested, material testing, and certification records. Test plan shall be submitted to the Technical Representative for approval at least [30] [_____] calendar days prior to the start of testing.

1.5 QUALITY ASSURANCE PLAN

Contractor shall prepare a quality assurance plan which provides a detailed outline of all testing to be accomplished. Quality assurance plan shall address whether cladding modes have been stripped prior to testing, source wavelength (peak), spectral width full width/half maximum (FWHM), mode structure, fiber end preparation, and bandwidth measurements of fiber links both greater and less than 1 kilometer. Quality assurance plan shall include, as a minimum, a schedule of when tests will be performed relative to installation milestones, specific test procedure that will be used, a list of test equipment that will be used including manufacturer, model number, range, resolution accuracy and shall conform to the specified requirements.

1.6 STORAGE AND HANDLING

Care shall be exercised in handling materials during construction. Contractor shall ensure that the buried cable is fed through the plow into the ground at zero tension. Tension shall not be allowed to develop in the cable.

Whenever the plow is stopped, sufficient cable shall be unreeled to guard against sudden jerks when the plow is started.

Caution shall be exercised to ensure that the plow is not backed up while the blade is in the ground. Cable can be severely damaged by the plow backing up even a slight amount. During the plowing operation, the plow may strike a buried object or rock that would stop the equipment and necessitate removal of the plow from the ground. When this occurs, the plow shall be removed carefully without backing up. When it is necessary to back the plow, the cable shall be uncovered a sufficient distance back from the plow for inspection by the Contracting Officer to determine if there is any damage. Any damage shall be immediately reported to the Contracting Officer. Damages shall be repaired or replaced as directed by the Contracting Officer.

PART 2 PRODUCTS

2.1 FIBER OPTIC CABLE DESIGN

2.1.1 Cable Length

Cable shall be manufactured continuous with no factory splices.

2.1.2 Materials and Construction

Materials used within a given cable shall be compatible with all other materials used in the same cable when such materials come into intimate contact. All cable components used shall have no adverse affect on optical transmission or on the mechanical integrity characteristics of the fiber placed in the cable. All materials used shall be non-toxic, non-corrosive, and shall present no dermal hazard.

Minimum required material components applied to fiber optic cable construction shall be central core member, color-coded optical fiber, color-coded loose tube buffer with gel-filling, gel-filling around loose tube, inner jacket, pulling strength members, and outer jacket. Variations in sequence and construction structural components will be considered when necessary.

2.1.2.1 Central Core Member

A central core member shall be included to serve as a cable core foundation to reduce strain on the fibers but not to serve as a pulling strength member. Material of the central core member shall be non-metallic.

2.1.2.2 Optical Fibers

Two types of optical fibers, single-mode fiber and multi-mode fiber, shall be contained in the cable and shall be as follows:

Single-Mode (SM) fiber must be the equivalent [step] [graded] index optical glass. Core diameter of the fiber shall be approximately 8.7

micrometer. Cladding diameter shall be 125 plus or minus 3 micrometer. Core cladding offset shall be less than 1 micrometer. Minimum tensile strength of the fiber after primary protective coating shall be greater than 50,000 psi 350,000 kilopascal . Softening point of the clad material of the optical fiber shall be 1630 degrees C plus or minus 50 degrees C in accordance with ASTM C 338, or the optical fiber shall meet the requirements in paragraph entitled, "Splice Compatibility Test."

Multi-Mode (MM) fiber shall be the [graded] [step] index optical glass. Core diameter of the fiber shall be [50] [62.5] plus or minus 3 micrometer. Cladding diameter shall be 125 plus or minus 3 micrometer. Core-cladding offset shall be less than 3 micrometer. Minimum tensile strength of the fiber after primary protective coating shall be greater than 50,000 psi 350,000 kilopascal. Softening point of the clad material of the optical fiber shall be 1630 degrees C plus or minus 50 degrees C in accordance with ASTM C 338, or the optical fiber shall meet the requirements in paragraph entitled, "Splice Compatibility Test."

2.1.2.3 Fiber Primary Protective Coating

Optical fiber shall be coated with suitable material to preserve the intrinsic high tensile strength of the glass fiber. Outside diameter of the coated optical fiber shall be 250 plus or minus 15 micrometer. Coating material shall be readily removable, mechanically or chemically, without damaging the optical fibers when the removal is desired.

2.1.2.4 Optical Fiber Color-Code Coating

Primary protective coated SM and MM fibers shall be coated with a color-code coating for individual fiber identification. Maximum outside diameter of color-code coated fiber shall be less than 300 micrometer.

2.1.2.5 Loose Tube Buffering

Color-code coated fiber[s] shall be surrounded with a loose tube buffering for protection from external mechanical and environmental influences. Interior of the tube shall be filled with a suitable gel-fitting compound to prevent water migration. Loose tube buffering shall be color coded for the tube identification. Material of the buffering tube shall be [PVC] [mylar] [nylon] [_____].

2.1.2.6 Colorants

Color concentrates or inks used to color code the optical fibers and the loose buffer tube shall not be susceptible to migration and chemical reaction with gel filling compound.

2.1.2.7 Number of Fibers Per Tube Per Cable

36-fiber cable and 72-fiber cable are required and shall be as follows:

36-fiber cable shall contain multimode and single mode fibers. Cable core configuration shall be comprised of six loose buffer tubes, each containing six fibers. Six fibers in each loose buffer tube shall be color coded using the first colors of the standard Munsell color code, Blue, Orange, Green, Brown, Slate, and White. Loose buffer tubes shall be color coded using the standard Munsell color code, Blue, Orange,

Green, Brown and Slate. Sixth buffer tube shall be Pink. Single mode fibers shall be considered last in configuration.

72-fiber cable shall contain multimode and single mode fibers. Cable core configuration shall be comprised of 12 loose buffer tubes, each containing six fibers. Six fibers in each loose buffer tube shall be color coded using the first colors of the standard Munsell color code, Blue, Orange, Green, Brown, Slate and White. Loose buffer tubes shall be color coded using the standard Munsell color code, Blue, Orange, Green, Brown, Slate, Red, Black, Yellow, and Violet. Eleventh and twelfth buffer tubes shall be Blue/White and Orange/White, respectively. Single mode fibers shall be considered last in configuration.

2.1.2.8 Inner Jacket

Buffer tubes shall be located concentrically around the cable central core member and covered with a polyethylene inner jacket. Polyethylene inner jacket shall be [high] [medium] density polyethylene in accordance with ASTM D 4976. Space between the buffer tubes and inner jacket shall be filled with a gel compound to prevent air, moisture, or water intrusion in the inner jacket.

2.1.2.9 Filling Compound

Inner jacket interior and loose tube buffer cavity shall contain a gel-type filling compound. Filling compound shall be of suitable viscosity so that it will protect the optical fibers against the ingress of water and/or soluble chemicals and shall not flow at the temperature of up to 65 degrees C. Gel filling compound shall be electrically non-conducting, inert gel-type, waterproof compound, non-toxic, with no dermal hazards, and compatible chemically and mechanically with all cable components and associated splice hardware materials to which it may make contact. Gel filling compound shall be removable, as required, using commercially available products under field-type conditions.

2.1.2.10 Pulling Strength Member

Aramid type material shall be used as pulling strength members in the cable to provide pulling strength of at least [400] [_____] pounds [1800] [_____] newton for the cable during installation.

2.1.2.11 Cable Outer Jacket

Black [high] [medium] density, high-molecular weight, polyethylene materials in accordance with ASTM D 4976 shall be applied longitudinally over all the inner jacket and sheathing strength member to form the cable outer jacket. Outer jacket shall be smooth, concentric, non-nutrient to fungus, and free from holes, splits, blisters, or other imperfections. Overall outside cable diameter shall not exceed [0.75] [_____] inch. [19] [_____] millimeter.

2.1.2.12 Metallic Armor

A metallic armor shield for direct buried cable shall be provided for additional tensile strength, rodent protection, and high crush and moisture resistance. Material of the metallic armoring shall be metallic tube or steel corrugation-coated with anti-corrosion material, sealed at the longitudinal overlap.

2.2 CABLE IDENTIFICATION SYMBOL

First of three lines on the ID symbol employ 5 characters.

First and second characters, from left to right, shall denote the number of active optical fibers in the cable.

Third character shall be a slash.

Fourth and fifth characters shall denote optical transmission windows which the optical fiber can support. These windows are defined herein as follows:

Fourth character shall be an "A" or an "O." The "A" denotes a window at a wavelength of 850 nanometers (nm) with an attenuation of 4 dB/kilometer (km) and a bandwidth of 800 MHz-km. Character shall be an "O" if these requirements are not met.

Fifth character shall be a "B" or an "O." The "B" denotes a window at a wavelength of 1,300 nanometer (nm) with an attenuation of 1.0 dB/km and a bandwidth of 1,000 MHz-km. Character shall be an "O" if these requirements are not met.

Two lower lines of the cable ID symbol indicate multi-mode or single mode fibers, the cable number and the fiber count:

Example: 72/OB	Identifies the number of optical fibers (72) and the optical transmission window (OB - See preceding paragraph).
FM05 : 61-120	Identifies Multi-Mode Fiber Cable 05 with MM Fibers 61 through 120.
and FS05 : 13-24	Identifies Single Mode Fiber Cable 05 with SM Fibers 13 through 24.

2.3 REPLACEMENT CABLE

In addition to the cable sections indicated, a reel of each size and type of the manufacturer's furnished cable, not less than 0.5 kilometers shall be provided.

2.4 SPLICE ORGANIZERS

Single mode or multi-mode fibers shall be fusion spliced with a protective sleeve covering and stored in an organizer with a minimum of 18 inches 450 millimeter spare coiled buffer tubing. Single mode fibers shall be spliced last in the splice tray.

A [72] [_____] fiber splice shall be completed in an outer closure. Organizer assembly, with one tray containing [12] [_____] fusion splices each requires [five] [_____] extra trays, to form the section complete in the inner closure.

Space between the inner and outer closures shall be filled with encapsulating fluid. End plates shall be factory drilled to fit the cable(s) outer diameter.

2.5 PRE-CONNECTED CABLE ASSEMBLY

Contractor shall supply factory assembled pre-connectorized cable assembly to interface with the patch panel bulkhead feed-through receptacle. Contractor shall supply and install dust caps for all terminated fibers.

Multi-mode fiber optic cable assembly shall be comprised of a single fiber connector, terminated on [three (3)] [_____] meter length of single fiber, multi-mode cable. Single fiber cable shall contain a buffered optical fiber and shall be the same as that provided in the multi-fiber cable.

Single fiber optic cable assembly shall be comprised of a single fiber connector terminated on the [three (3)] [_____] meter length of single fiber, single mode cable. Single fiber cable shall contain a buffered optical fiber and shall be the same as that provided in the multi-fiber cable. Return loss for single mode connectors shall be a minimum of [minus 30dB] [_____].

Connector/cable interface on both the single and multi-mode cable assemblies shall be able to withstand a tensile force of [25] [_____] pounds [110] [_____] newton without detrimental affects on the connector loss characteristics.

Each connectorized cable assembly shall have a loss of less than or equal to [0.5 dB] [_____].

2.6 OPTICAL PATCH PANEL ASSEMBLIES

All cable terminations shall be made in optical patch panel assemblies. Patch panel assemblies shall be of the pre-assembled chassis type with associated rack-mounting hardware.

To facilitate the transition between outside plant cable and the preconnectorized cable assemblies, the fibers shall be [fusion] [mechanical] spliced and housed in a splice tray. Splice tray shall be positioned in the optical patch panel assembly as indicated. Splice attenuation shall not exceed [0.2] [_____] db. Splice shall be covered with a protective sleeve.

2.7 FIBER OPTIC TERMINAL CABINETS

FOT cabinets shall be front recess only. Cabinet's frame shall consist of vertical and horizontal tubular aluminum extrusions with a minimum wall thickness of [.150] [_____] inches [3.81] [_____] millimeter. Front to rear aluminum extruded corners shall be at least [.125] [_____] inches [3.18] [_____] millimeter thick. Rear door, top panel, and side panels shall be a minimum of [18] [_____]-gage [1.3] [_____] millimeter steel. Cabinet shall be provided with [14] [_____] gage [1.9] [_____] millimeter steel, [.281] [_____] inches [7.14] [_____] millimeter punched panel/chassis mounting rails permitting recessed installation of equipment. Cable entry and exit holes shall be placed as indicated. Dimensions of cabinet and associated cabinet hardware shall be as indicated.

Cabinet shall be gray in color in accordance with FED-STD 595.

2.8 FACTORY TEST CERTIFICATES

Fiber optical cable shall comply with the following optical and mechanical test requirements.

2.8.1 Optical Performance

2.8.1.1 Multi-Mode Fibers in the Cable

Optical attenuation of each optical fiber in the cable (reeled) shall be no greater than 1.0 dB/Km at 1300 plus or minus 50 nm optical spectrum window. Attenuation shall be measured on completed cable reel length, and normalized linearly to 1 Km. Measurement method shall be in accordance with [EIA 455-46A] [EIA 455-53A] at central wavelength 1300 nm nominal.

Bandwidth at minus 3 dB optical power of each optical fiber in the cable (reeled) shall be a bandwidth length product, gamma equals 1, greater than 1 GHz-Km at 1300 plus or minus 50 nm optical spectrum window. Bandwidth measurement shall be in accordance with [EIA 455-30B, frequency domain] [EIA 455-51A time domain] at central wavelength 1300 nm nominal.

Numerical aperture of each optical fiber shall be 0.2 plus or minus 0.015 at 1300 nm optical spectrum window. Method of numerical aperture measurement shall be in accordance with EIA 455-47B, at central wavelength 1300 nm nominal. When this requirement is not met, the fusion splice compatibility test shall be applied.

2.8.1.2 Single-Mode Fibers in the Cable

Optical attenuation of each optical fiber in the cable (reeled) shall be no greater than 0.5 dB/Km at 1300 plus or minus 50 nm optical spectrum window. Attenuation shall be measured on completed cable reel length, and normalized linearly to 1 Km. Measurement method shall be in accordance with EIA 455-78B, at central wavelength 1300 nm nominal.

Pulse dispersion of each optical fiber in the cable (reeled) shall be no greater than 3.5 picosecond/nm-Km within the emissive region of 1285-1330 nm. Measurement method shall be in accordance with [EIA 455-168A] [EIA 455-169A].

Mode field diameter at 1300 nm optical spectrum window shall be within 10 plus or minus 1 micrometer. Measurement method shall be in accordance with [EIA 455-164A] [EIA 455-165] [EIA 455-167A] at central wavelength 1300 nm nominal. When this requirement is not met, the fusion splice compatibility test shall be applied.

Cut-off wavelength for 1300 nm optical spectrum window shall be within 1200 plus or minus 70 nm. Measurement method shall be in accordance with EIA 455-80B.

2.8.2 Mechanical Performance

2.8.2.1 Minimum Bend Radius

Cable shall be able to withstand bending to a minimum radius of [10] [_____] times the cable outer diameter without tensile load applied, and of [20] [_____] times the cable outer diameter with maximum tensile load applied (during installation), without damage to cable components or degradation of the optical fiber performance at room temperature.

2.8.2.2 Tensile Strength

Fiber optical cable shall withstand a pull force of at least [1800] newtons

[(400 pounds)] [_____] to be applied to the pulling strength member during the installation, and a tensile load of at least [300] [_____] newtons during operation without incurring any damage or detriment to fiber optical cable and optical performance. Tensile strength test shall be in accordance with EIA 455-33A.

2.8.2.3 Flexing or Bending Cycles

Fiber optical cable shall withstand at least [20] [_____] bending cycles at minimum bend radius without damage to the fiber optic cable components or degrading optical performance. Cyclic flexing test shall be in accordance with EIA 455-104A.

2.8.2.4 Crush Resistance

Minimum crush resistance of the fiber optical cable shall be greater than 650 newton/centimeter (cm) without damage to cable components or degrading optical performance. Crush resistance test shall be in accordance with EIA 455-41.

2.8.2.5 Impact Resistance

Fiber optical cable shall be capable of withstanding [20] [_____] impacts, at five newton-meters force, without damage to cable components, or degradation of optical performance. Impact resistance test shall be in accordance with EIA 455-25C.

2.8.2.6 Gel Filling Compound Drip Test

Optical cable shall be tested for the ability of the gel filling compound in the interior of the inner jacket and loose tube buffer to resist flow at the temperature range of minus 40 degrees C to 60 degrees C in accordance with EIA 455-81B.

2.8.2.7 Fluid Penetration

Optical cable shall be capable of preventing the entry and axial migration of pressurized water when subjected to fluid penetration testing in accordance with EIA 455-82B.

2.9 TEMPERATURE ENVIRONMENT

Fiber optical cable shall comply with the mechanical performance requirements herein while used in duct applications where the temperature varies from minus 8 degrees C to plus 38 degrees C. Optical performance degradation shall be less than [five] [_____] percent of the optical performance requirements in the temperature range of minus 20 degrees C to plus 60 degrees C. Fiber optical cable shall not be damaged in storage where the temperature may vary from minus 40 degrees C to plus 65 degrees C.

2.10 SPLICE COMPATIBILITY TEST

When the material of the optic fiber is different from Cornings' Class Code No. 1517 for multi-mode graded index fiber and No. 1528 for single-mode fiber, the Splice Compatibility Test shall be performed and documented as follows:

Vendor shall select fiber samples from a minimum of [3] [_____] different production lots of the fiber type proposed for the job.

Vendor shall fabricate and measure a minimum of [10] [_____] fusion splices using fiber from the different production lots and a sample of Corning fiber, Class Code No. 1517 and No. 1528, supplied by the Government.

Fusion splices shall be measured using an Optical Time Domain Reflectometer (OTDR) operating in the region of 1250 through 1350 nm. The insertion loss of the fusion splice shall be the average of two OTDR measurements, one taken with the OTDR installed on the Corning fiber, and the other with the OTDR installed on the vendor's fiber. Vendor's fiber and the Corning fiber shall each be a minimum of 1 Km in length throughout the testing.

Vendor's fiber shall be considered compatible with the Corning fiber if the maximum splice insertion loss of each of [10] [_____] fusion splices tested measures less than 0.2 dB.

Vendor shall be allowed a maximum of three retries on any one splice to obtain a loss of 0.2 dB or less.

These tests shall be performed under Government supervision.

PART 3 EXECUTION

3.1 FIBER SPLICES

Outside plant fiber splices shall be [fusion] [mechanical] type and made along the fiber route. Splices shall exhibit an insertion loss not greater than 0.2 dB. All splice measurements shall be made at 1300 nm, plus or minus 5 nm. All splices shall be mounted in trays. Number of splices shall not be increased.

Completed splice shall be covered with a protective sleeve heat shrink type to restore the protective properties of the fiber coating and buffering. Deviations to the splice, location and pulling plan will be permitted, upon approval by the Contracting Officer, and shall be provided at no additional cost to the Government.

All fiber colors shall be continuous from end to end. No switching or staggering of color scheme within the cable at splice points shall be allowed. Fibers shall be spliced in order with multi-mode fibers identified first and single mode fibers at the end.

Cables shall be brought out of the manhole in a controlled environment to perform the fiber fusion splice operation. Splice shall be completed by returning the cable to the manhole such that the excess cable does not impede future entrance and utilization. Cable shall be secured at regular intervals.

3.2 BURIED CABLE INSTALLATION

3.2.1 Location

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NOTE: Buried cable installation refers to the placement of cables directly in the ground without protection other than their own outer coverage (jackets). The overall buried cable installation

may include manholes and hand holes, for splicing, terminating and pull-through purposes.
****

Location of the cable splice overlaps shall be as indicated. Contractor shall ensure that all cable ends are sufficiently long before cutting.

3.2.2 Field Staking

When staking the cable plow or trench line, stakes shall be placed at least every 100 feet 30 meter in level country and more frequently in rolling country or in dense vegetation, so that the construction force can sight at least two successive stakes at all times. Stakes should be placed at changes in direction, the beginning and end of all turns should be staked clearly. Where existing buried cable is encountered within [2] [_____] feet [600] [_____] millimeter of the proposed line, the distance between stakes shall be decreased to a minimum of [10] [_____] feet [3] [_____] meter. When possible, stakes should project above the vegetation along the line. When a road or other crossings are involved, stakes should be placed at both extremes of the right-of-way.

A stake, with the appropriate number or explanation noted on it, should be used to show the location of each caution point, such as underground utility crossings and culverts; miscellaneous points, such as physical cable protection; and buried cable warning sign locations.

3.2.3 Method of Cable Placement

****
NOTE: Method used in placing the cable will depend on the exact location of the route, obstructions encountered, soil conditions, and topography of the route. Method which best suits the local conditions and which produces the least amount of disturbance or damage to existing utilities and surrounding areas should be used. Under certain conditions, combinations of placing methods may be advantageous.
****

All direct buried cable shall have a warning tape placed above it as indicated.

Depth of buried cable in soil measured from the top of the cable to the surface of the ground shall be a minimum of [30] [_____] inches [800] [_____] millimeter, when existing utilities are crossed, hand excavation shall be used at a distance of no less than [four] [_____] feet [1.3] [_____] meter on each side of the utility.

3.2.3.1 Open Trench Method

Contractor shall observe the following when placing cable by the open trench method:

Trench shall be free of all rock and debris.

Cable shall be pulled from cable reel truck or dolly and shall be placed in the trench by hand.

Cable shall be placed in trench as soon as practical and backfilled

immediately to avoid cave-in, and ensure safe operational conditions.

An inspector shall walk closely behind the cable reel dolly and ensure that the cable lies flat on the trench bottom, and is placed at the required minimum depth.

Cable shall be pulled by hand on each end simultaneously, to remove excess slack, prior to backfilling.

Trench shall be backfilled in [six] [_____] inch [150] [_____] millimeter lifts to ensure proper fill. Each backfill lift shall be compacted with hand tamp tools. First lift shall be hand tamped prior to placing the cable.

3.2.3.2 Direct Plow Method

Contractor shall observe the following when placing cable by the direct plow method:

Plow shall be clear of any obstruction which may damage cable and ensure that all rollers on the tractor and on the plow turn freely and are properly located.

Cable shall be hand fed off the reel at all times to ensure that no damage is done to the cable due to excess tension.

An inspector shall walk closely behind the plow and inspect the cable for any blemish or damage, and ensure a free and continuous flow of the cable from the reel to the plow. Inspector shall ensure that the cable is plowed at the minimum required depth.

3.2.4 Compaction

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NOTE: The following method of compaction is recommended: Run the tractor track or tire along and immediately adjacent to both sides of the plow slot; fill in any ground depressions which may develop with earth to form a mound over the center of the plow slot; and then run the tractor tire over the center slot. Different soil conditions may warrant that other methods of compaction be employed.
****

Plow slot shall be compacted following the plowing in or trenching of wire or cable.

3.3 UNDERGROUND CABLE INSTALLATION

Inner duct assignment of individual cables shall be as indicated. Cables shall not be placed in ducts other than those specified.

Adequate care shall be exercised when handling and storing reels of cable to prevent damage to the cable. Cable with dents, flat spots, or other sheath distortions shall not be installed.

3.3.1 Securing Cable

Immediately after cable placement, a permanent identification tag as

indicated shall be attached to visible cable sections. Cables shall be checked to ensure that the markings are intact.

Cables and equipment shall be supported and secured as indicated. Where the specific method of support is not shown, supports and fasteners shall be used to secure cables and equipment in position. Metallic supports and fasteners shall have a corrosion resistant finish. All cables shall be routed along the interior sides of manholes.

Two or more cable hooks shall be required per manhole.

Clamps and straps shall be used as necessary to properly secure the cable.

3.3.2 Bending

Caution shall be used when bending cable to avoid kinks or other damage to the sheath. Bend radius shall be as large as possible with a minimum of [10] [_____] inches [250] [_____] millimeter. Minimum radius shall be increased when necessary to meet cable manufacturer's recommendation. Cables shall not rest against any sharp edges.

Cable shall be pulled and spliced in the manner and at the locations shown.

3.3.3 Pulling

Pulling lines shall be attached to both cable ends when cable is destined for bi-directional pull, and fitted with factory-installed pulling eyes. Cables not equipped with a pulling eye shall have the pulling line attached to the cable end by means of a cable grip. Core hitches shall not be used.

Cable reels shall be located and aligned so that the cable is payed out from the top of the reel into the duct or conduit in a long, smooth bend without twisting. Cable shall not be pulled from the bottom of the reel. A cable feeder guide of proper dimensions shall be used at the mouth to guide the cable into the duct or conduit.

Rigging shall be set up at the pulling end so that the pulling line and cable exit on a line parallel with the duct or conduit to prevent either from rubbing against the edge or mouth. Cable ends shall not be pulled around sheave wheels. When the sheave or pulley cannot be positioned to obtain sufficient cable end slack for proper racking and splicing with the pulling line attached to the end of the cable, a split cable grip may be used to obtain the necessary slack.

3.3.4 Lubricant

Pulling lubricant, shall be used to minimize pulling tension and prevent sheath damage when pulling cables into ducts and conduits. Lubricant shall be applied to the cable sheath with a lubricator. When pulling has been completed, the exposed cable ends shall be wiped clean of lubricant.

Lubricants shall be compatible with and intended for use with plastic-sheathed cables. Soap and grease type lubricants shall not be allowed.

All equipment and the pulling set shall be checked to minimize interruptions once pulling begins. Cable shall be pulled without stopping until the required amount of the cable has been placed. When the pulling operation is halted before the pull is completed, the tension of the

pulling line shall not be released. When pulling is resumed, the inertia of the cable shall be overcome by increasing the tension in small steps a few seconds apart until the cable is in motion. Cable shall be payed from the top of the reel by rotating the reel in the feed direction at the rate of pull. Cable shall not be stripped off the reel by pulling.

3.3.5 Damage and Defects

Contractor shall use a tension monitoring device to ensure that the maximum pulling tension that may be applied to the cable to be pulled into a conduit section is not exceeded. Any damage to the cable due to exceeding the maximum tension will require a new cable furnished by the Contractor.

Cable shall be carefully inspected for sheath defects or other irregularities as it is payed out form the reel. When defects are detected, pulling shall stop immediately and the cable section shall be repaired or replaced at the discretion of the Contracting Officer. A system of communications shall be maintained between pulling and feed locations so that pulling can be stopped instantly, when required.

Cable shall be hand guided through intermediate manholes and into the next duct section when making pull-throughs. Proper rigging shall be used in the intermediate manhole to keep the pulling line and cable aligned with the exit duct to prevent the line or cable from rubbing against the edge of the duct. Cables in pull-through manholes shall be set up and racked before the cable ends in adjacent manholes are set up and racked.

Cable ends pulled into manholes, vaults, or terminal locations that are not to be racked or otherwise permanently positioned immediately shall be tied in fixed positions to prevent damage to the cables and provide adequate working space.

3.3.6 Seal

Ducts or innerduct in which cable is placed shall be sealed with urethane foam duct seal. This material shall be inserted between the cable and the duct or innerduct of which it is in, between the innerduct and the duct, and in all unused innerduct, in order to prevent damage to the cable sheath and to prevent the entrance of dirt or water into the manhole or vault.

Cables shall be provided in continuous lengths as required to accomplish the required installation without splices from termination to termination, except where field splices are specifically shown.

3.4 CABLE INSTALLATION IN CABLE TRAYS

Communication cables shall not be installed in the same cable tray with ac power cables.

Cables placed in cable trays shall be installed in a neat and orderly manner and shall not cross or interlace other cables except at breakout points.

Cables in vertical trays shall be individually retained with straps at a maximum of [6] [_____] feet [1800] [_____] millimeter on center.

3.5 CABLE DELIVERY

Replacement cable reels shall be delivered to the Government as directed by

the Contracting Officer.

3.6 GROUNDING SYSTEMS

Cables shall be grounded at each termination point or as indicated.

3.7 TESTING

As a minimum, the Contractor shall test each fiber cable before and after installation for any faults or attenuations using an Optical Time Domain Reflectometer (OTDR). End-to-end attenuation tests shall also be conducted after complete installation.

All test equipment, test procedures, and testing techniques shall be specified in the quality assurance plan and will require approval prior to execution. Tests shall be conducted by the Contractor in accordance with the approved Quality Assurance Plan. Field tests shall be witnessed by the Contracting Officer. Contracting Officer shall be given at least [20] [_____] calendar days notice prior to performing each test.

Each test sheet shall have a sign-off blank for the Contractor as well as the Contracting Officer. Copies of the completed test forms and test results shall be delivered as indicated.

Sequential cable markings along the cable, prior to and after each end of splice point, shall be recorded on the sequential cable form and submitted for approval.

Test results shall be submitted on all installed fiber cabling before and after each pre-connectorized cable assembly splice is completed.

Contractor shall maintain an accurate test record during all field tests.

3.8 TEST REQUIREMENTS

Test equipment used for verifying installation testing shall be calibrated by a certified testing company within [3] [_____] weeks of use.

3.8.1 Single and Multi-mode OTDR Test

The Optical Time Domain Reflectometer (OTDR) shall conform to the following minimum requirements:

Operating wavelengths: [1,300] [_____] plus or minus 20 nanometers

Attenuation Range (one way): minimum [15] [_____] dB at 1,300 nm

Attenuation Resolution: [0.01] [_____] dB

Accuracy: plus [0.5] [_____] dB.

OTDRs shall have digital readout capability and shall have a means of providing a permanent record in the form of a [strip chart] [photograph] [_____].

3.8.2 End-to-End Attenuation Tests

An attenuation measurement test set shall consist of an optical power meter and an optical power source. Attenuation measurement test set shall be in

accordance with the applicable National Bureau of Standards (NBS) standards for a stable optical source. Meter may be analog or digital. End-to-end attentuation test reading shall be ioncluded on the test reference loss. Measurement test set shall conform to the following minimum requirements:

Operating wavelengths: [1,300] [_____] plus or minus 10 nanometers

Attenuation Range: at least [30] [_____] dB at 1,300 nm

Attenuation Resolution: [0.01] [_____] dB

Accuracy: The accuracy of the attenuation measurement test set shall be plus or minus [5] [_____] percent.

Optical source shall be capable of coupling sufficient power into the fiber so that the light received at the meter is within the meter detectability limits.

3.8.3 End-to-End Bandwidth Tests

Bandwidth test shall conform to the following minimum requirements:

Operating wavelengths: [1,300] [_____] plus or minus 10 nanometers

Bandwidth range: minimum [1000] [_____] megahertz

Bandwidth Resolution: [1] [_____] megahertz

Accuracy: plus or minus [0.5] [_____] megahertz

Measurement Method: [Swept Frequency] [_____]

-- End of Section --